Phys 112L
Spring 2019

Laboratory 7: Induction and Faraday's Law – Prelab

1 Ring in an increasing field

A metal ring is in a region with a uniform magnetic field as illustrated in Fig. 1. The magnitude of the field increases at a constant rate. Determine the direction of the current that this induces in the ring.

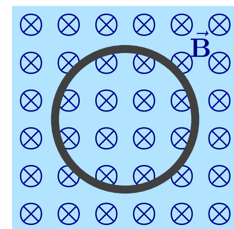

Figure 1: Ring in a field

2 Ring in an decreasing field

A metal ring is in a region with a uniform magnetic field as illustrated in Fig. 2. The magnitude of the field decreases at a constant rate. Determine the direction of the current that this induces in the ring.

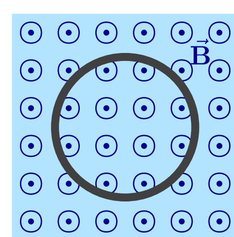

Figure 2: Ring in a field

Laboratory 7: Induction and Faraday's Law – Activity

1 Faraday's Law: Ring and Magnet

A metal ring is held fixed while a bar magnet is positioned along the axis of the ring as illustrated in Fig. 3.

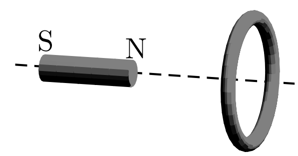

Figure 3: Ring and magnet

a) Suppose that the magnet is held fixed. Sketch the magnetic field produced by the magnet inside the ring. Does the magnet produce a current in the ring? If so, what is the direction of the current (as viewed from the right edge of the page)? Explain your answers.

b) Suppose that the magnet is moved *toward* the ring at a *constant speed.* Does the magnet produce a current in the ring? If so, what is the direction of the current (as viewed from the right edge of the page)? Explain your answers.

c) Suppose that the magnet is moved *toward* the ring at a constantly *decreasing speed.* Does the magnet produce a current in the ring? If so, what is the direction of the current (as viewed from the right edge of the page)? Explain your answers.

d) Suppose that the magnet is moved *away from* the ring at a *constant speed.* Does the magnet produce a current in the ring? If so, what is the direction of the current (as viewed from the right edge of the page)? Explain your answers.

2 Faraday's Law: Ring and Solenoid

A metal ring is placed near the right end of a large solenoid as illustrated. The left end of the solenoid is connected to the positive terminal of a battery and the right end to a switch, which is connected to the negative end of the same battery.

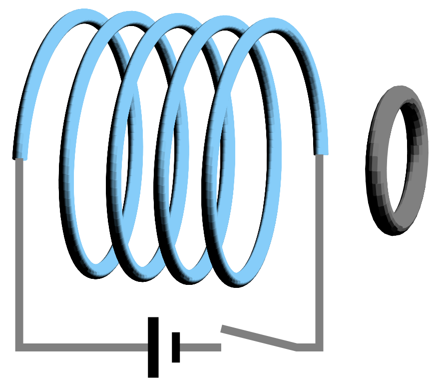

Figure 4: Ring near a solenoid

a) The ring and the solenoid are held stationary with respect to each other. For each interval listed below explain whether there is a current induced in the ring.

  i) Before the switch is closed.

  ii) While the switch is closing.

  iii) A long time after the switch is closed.

b) Consider the period during which current actually flows through the ring. Sketch the magnetic field vector (produced by the solenoid) at the ring at the beginning of this period.

Sketch the magnetic field vector (produced by the solenoid) at the ring at the end of this period.

Use these sketches to describe the change in the magnetic field vector (produced by the solenoid) at the ring during the period while the current flows. Use this and Lenz's law to determine the direction of the induced field that is produced by the induced current. Sketch this below.

Use your previous answer to determine the direction of the induced current which flows through the ring.

c) While the switch is closed, the solenoid is held fixed and the ring is moved to the right. Explain whether any current flows through the ring and, if so, what the direction of the current is (use the type of reasoning of part b)). Explain whether it is possible to attain the same effect by keeping the ring fixed and by moving the solenoid.

d) While the switch is closed the ring is moved to the right from a fixed initial location to a fixed final location. This is done twice using the same initial and final locations, moving the ring at different speeds. Explain whether the current when the ring is moved slowly is equal to, larger than or smaller than that when it is moved quickly.

e) The experiment is duplicated by using an identical solenoid and battery but a different ring. This second ring has the same dimensions but is made from a different material with exactly double the resistivity. The two rings are held the same distance from their respective solenoids. While the switches are closed, the rings are moved away from the solenoids in the same direction and at the same rate. Explain whether the EMF around the second ring is equal to, larger than or smaller than the EMF around the aluminum ring.

f) In the scenario of the previous question, describe as precisely as possible how the current through the second ring compares to the current through the aluminum ring. Explain your answer.

g) If the previous scenario were repeated using a third ring, with the same dimensions but made from a material that is a very poor conductor (i.e. a nearly perfect insulator), how would the EMF around this loop compare to that around the aluminum ring? Explain your answer.

h) Consider a ring made of a nearly perfect insulator and the aluminum ring each placed in the vicinity of identical solenoids. The dimensions of the rings are the same and they are in the same locations relative to their solenoids. The current through each solenoid is increased at the same rate. How will the EMFs around the two rings compare? Explain your answer. Does your answer change if one of the rings is replaced by an imaginary ring of air?

3 Faraday's Law: Experimental Observations

The PASCO RLC Circuit board contains a coil through which a magnet can be moved. The potential difference across the coil can be measured as a function of time, thus enabling experimental observations of Faraday's Law.

a) Attach the PASCO RLC Circuit board with enough space beneath it so that one of the magnets can drop all the way through.

b) Take a cylindrical neodymium magnet and determine which are its north and south ends. You will drop the magnet, north end first through the coil. Indicate the direction of the magnetic field produced by the magnet as it passes through the coil. Explain whether the direction of the magnetic field changes as the magnet passes through the coil.

c) Connect the voltage sensor to the coil terminals on the board. Open Capstone, connect the voltage sensor. Set the sample rate to 1000 Hz. Display the output of the voltage sensor in a graph window. This displays a graph of the EMF versus time across the coil.

d) Start the voltage sensor, drop the magnet, north end first, through the coil and catch it before it lands. Observe the graph of EMF vs. time (you may need to rescale the graph to notice its interesting features). Save the data and graph.

e) The graph of the EMF versus time should show two instants at which the *magnitude of the EMF* is large. Explain how the sign of the EMF at the earlier instant compares to that at the later instant.

Taking your answer to part 3 b) into account, explain why the sign of the EMF reverses.

Also, at one of the two instants, the magnitude is noticeably larger than at the other. Provide a physical reason for this.

f) Repeat part 3 d) with the magnet reversed. Save the data and graph. Compare the resulting graph to that obtained before and provide a physical reason for the major difference between the two graphs.

g) Hold the magnet stationary outside the coil and observe the graph of EMF vs. time. Describe whether this agrees with Faraday's Law. Repeat this for the magnet held stationary inside the coil. Save the data and the graph.

h) Display the three graphs from the previous three parts on a single sheet, labeling the three graphs and attach it to the worksheet.